ERSKINE & NAU

Applicability of the Stadia to Land Surveying

Civil Engineering

B. S.

1912

APPLICABILITY OF THE STADIA TO LAND SURVEYING

BY

ALEXANDER WATMOUGH ERSKINE
AND
ROBERT HAROLD NAU

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

1912

UNIVERSITY OF ILLINOIS

COLLEGE OF ENGINEERING.

May 24, 1912

This is to certify that the thesis of ALEXANDER WATMOUGH ERSKINE and ROBERT HAROLD NAU entitled APPLICABILITY OF THE STADIA TO LAND SURVEYING was prepared under my personal supervision; and I recommend that it be approved as meeting this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

G. W. Pickels

Instructor in Civil Engineering.

Recommendation approved:

Ira O. Baker

Professor of Civil Engineering.

A GENERAL DISCUSSION.

The object of this investigation is to determine the accuracy which can be secured in land surveying by the stadia measurement of distance. To facilitate in this work, fields in the University of Illinois' triangulation system were used in which the lengths of the lines are known to the hundredth of a foot and the angles to five seconds; and hence a reliable check was obtained upon the areas of the fields and upon the stadia measurement of each line.

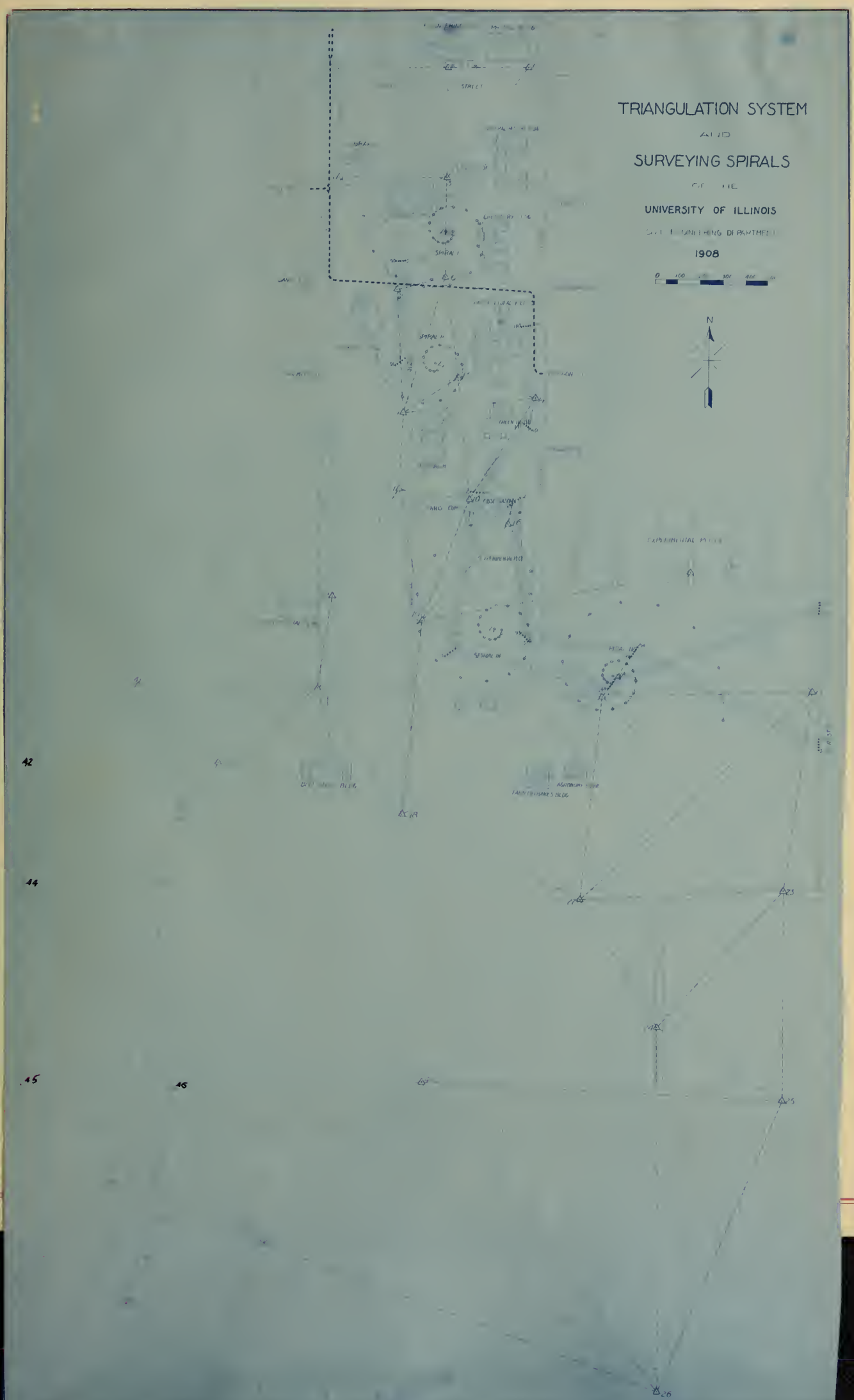
The usual way of surveying land is by means of the transit and tape. This method easily gives an accuracy in the area of 1:3000, and should be used where land is expensive. Where this is the case, the cost of the survey is relatively small as compared with the price of the property; but where land is cheap, the use of an inexpensive method is desirable. Naturally stadia surveying presents itself, because the number of men and the time required to do the work is less than for a transit and tape survey.

The chief source of error in stadia surveying lies in the determination of the stadia factor. This factor is usually determined by the first person using the instrument for such work and is used with that instrument in any further surveys. Still others assume the factor as one hundred. In this work the factor

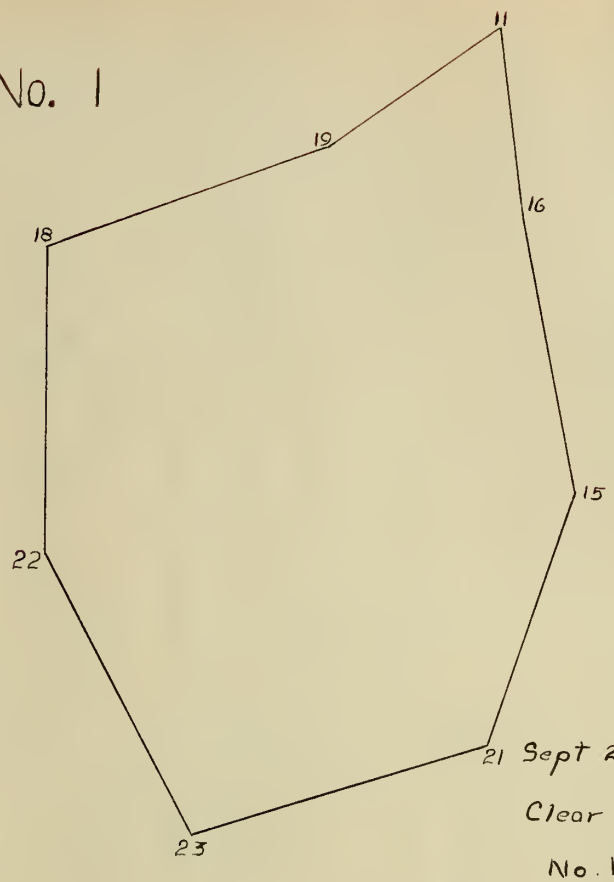
was determined to the hundredths place. An investigation along this line by Professor L. S. Smith, of the University of Wisconsin, has shown that both weather conditions and the personal equation of the observer produce noticeable errors and must be taken into account. Professor Smith's experiments, extending over two summers, demonstrated that stadia measurements could be made with an accuracy very close to that of chaining. He made a study of weather conditions and their effect upon the stadia readings, and found that during the summer months, the vibrations of the atmosphere caused a noticeable error. The air is heated by contact with the earth, and when the layer of air nearest the ground becomes heated, it expands and rises, causing a stratum of less density near the ground than a few feet above it. It also creates columns of warm air, which act as hugh lenses, and a line of sight passing through them is bent. This brings the two lines of sight closer together. The effect of the difference in density of the layers of air is to refract the lines of sight differently, the upper one being bent less than the lower one because of a more stable condition of the air. This difference in the refraction is what Professor Smith terms differential refraction. This is more noticeable between the hours of 9:00 A.M. and 3:00 P.M. Before 9:00 A.M. the ground has not received enough heat from the sun to warm the air sufficiently to cause a difference in density, while after 3:00 P.M. the ground and air immediately above it are nearly the same temperature. By taking into account these errors, Professor Smith was able to run a line of twenty miles in length with an error of 1:11400, and another line of thirty miles in length, using sights of 1100 to

2000 feet, with an error of 1:1741. This degree of accuracy was the result of care, far beyond that which could be used in an ordinary survey; but the theory may be carried into such work, and has been attempted in this investigation. The stadia factor was determined for the conditions under which each survey was made. Most of the work was done early in the afternoon from 1:00 to 4:00, and the stadia factor was determined just before the survey was started. In this way the effect of vibrations and differential refraction upon the survey were eliminated by incorporating the same errors in the stadia factor as occurred in the stadia measurements. Two observations were taken of both a full and a half rod-intercept in determinating the factor on lines approximately the length of the majority of the sights. The average of the two observations was used as the factor. The areas were determined by the latitude and departure method and logarithms were used in the computations.

Chicago stadia rods, twelve feet in length, having two 8" x 8" targets were used in the field work. One target was set at the top of the rod while the other was manipulated by the rodman who read the intercept and signalled it to the instrumentman. A Keuffel and Esser transit was used.


TRIANGULATION SYSTEM
AND
SURVEYING SPIRALS
OF THE
UNIVERSITY OF ILLINOIS
1908
N
STREET
SPIRAL I
SPIRAL II
SPIRAL III
42
44
45
46
23
26

Field No. 1



Inst. Erskine

Rod. Nau

21 Sept 26th 1911 Time 1:30 - 5:00

Clear, Bright, Windy

No. Vibrations Temp 65°

Sta.	Obj	Angle	Rod Intercept	Stadia Distance	Triangulation Distance	Difference
18	22					
	19	109° 36'	4.293 *	860.96	862.73	- 1.77
19	18					
	11	196° 00'	5.902	591.79	590.42	+ 1.37
11	19					
	16	61° 53'	5.041	505.60	508.11	- 2.51
16	11					
	15	183° 7'	4.163 *	834.93	834.73	+ 0.20
15	16					
	21	150° 7'	7.511	752.85	751.90	+ 0.95
21 -	15					
	23	126° 21'	8.895	891.38	890.22	+ 1.16
23	21					
	22	100° 18	8.940	895.90	894.91	+ 0.99
22 -	23					
	18	152° 41	4.301 *	862.56	865.89	- 3.33

Stadia Factor

	Whole Intercept	Half Intercept
21 - 23	8.875	4.439
20	9.248	4.632

*Half Intercept

Field No. 1.

Line	Length	Angle	Log. Sin.	Log. Cos.	Log. Length	Log. Lat.	Log. Dept.	Log ½ Mean	Log Product	Product.
18-19	860.96	70°24'	9.97408	9.52563	2.93498	2.46061	2.90906	2.60803	5.06864	-117,120
19-11	591.79	54°24'	9.91014	9.76501	2.77216	2.53717	2.68230	3.02188	5.55905	-362,280
11-16	505.60	7°29'	9.11474	9.99629	2.70381	2.70010	1.81855	3.12228	5.82238	+664,400
16-15	834.93	10°36'	9.26470	9.99252	2.92165	2.91417	2.18635	3.15682	6.07099	+1,177,600
15-21	752.85	19°17'	9.51883	9.97492	2.87671	2.85163	2.39554	3.14222	5.99385	+985,950
21-23	891.38	72°56'	9.98044	9.46758	2.95006	2.41764	2.93050	2.92274	5.34038	+218,970
23-22	895.90	27°22'	9.66246	9.94845	2.95226	2.90071	2.61472	2.31368	5.21439	-163,830
22-18	862.56	0° 0'	∞	0	2.93579	2.93579	0	0	0	0

Stadia Area = 2,403690 Sq. ft = 55.19 Acres

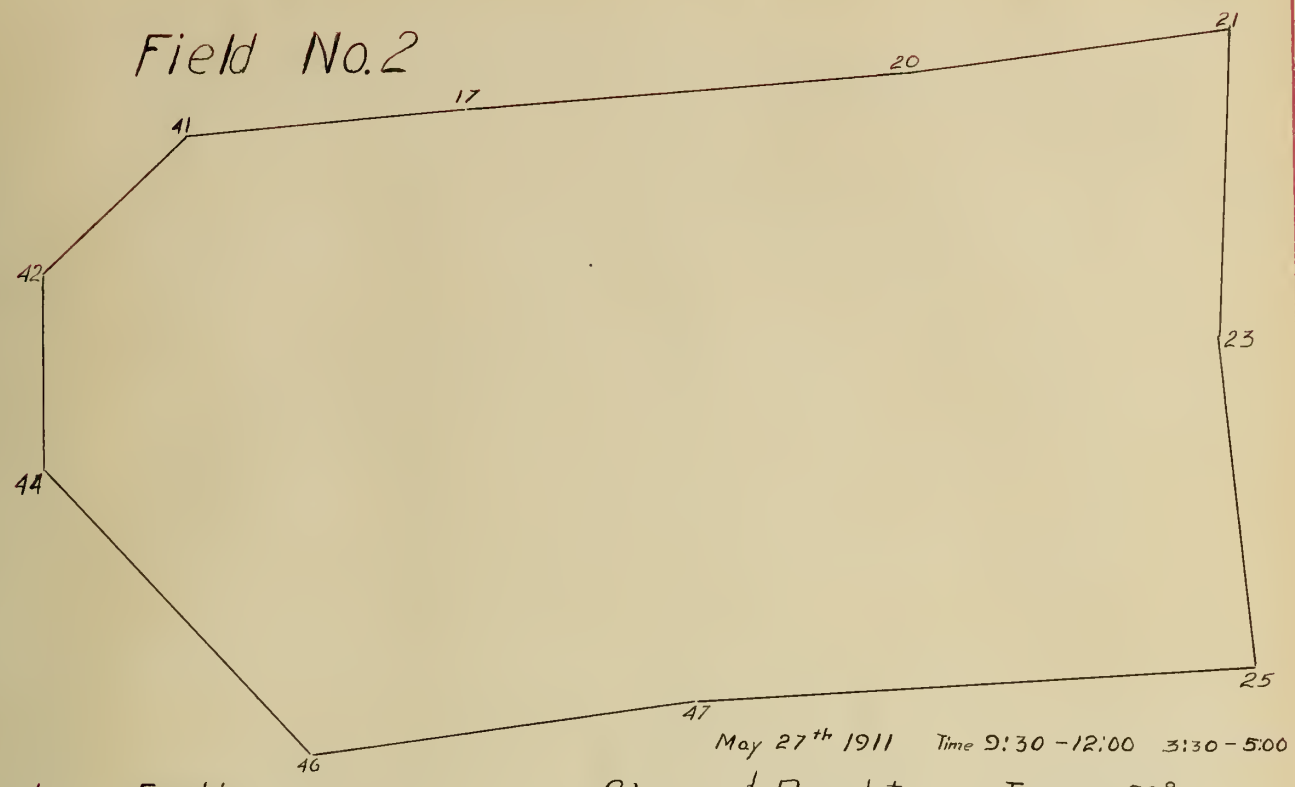
Triangulation Area = 55.26 "

-0.07 "

Error - 1/790

8

Field No. 2



May 27th 1911 Time 9:30 – 12:00 3:30 – 5:00

Inst. Erskine Clear and Bright Temp 80°

Rod. Nau Heavy Vibrations Light Wind

Sta.	Obj.	Angle	Rod Intercept	Stadia Distance	Triangulation Distance	Difference
42	44	133° 2'				
	41		5.600	562.41	564.02	– 1.61
41	42	142° 5'				
	17		7.930	795.98	791.89	+ 4.09
17	41	178° 53'				
	20		6.224 *	1251.00	1255.00	– 4.00
20	17	182° 59'				
	21		9.243	927.62	925.96	+ 1.66
21	20	80° 22'				
	23		8.866	889.82	890.42	– 0.60
23	21	188° 0'				
	25		9.214	924.72	925.25	– 0.53
25	23	87° 45'				
	47		7.920 *	1591.66	1585.70	+ 5.96
47	25	184° 26'				
	46		5.426 *	1090.75	1092.82	– 2.07
46	47	124° 42'				
	44		5.570 *	1119.70	1117.34	+ 2.36
44	46	137° 46'				
	42		5.510	559.74	557.84	+ 1.90

		Stadia Factor	
		Whole Intercept	Half Intercept
19	20	8.561	4.281
	11	5.893	2.940

* Half Intercept

Field No. 2

Line	Length	Angle	Log Sin	Log Cos	Log Length	Log Lat	Log Dept	Log ½ Mean	Log Product	Product
42-41	562.41	46° 58'	9.86389	9.83405	2.75006	2.58411	2.61395	2.31292	4.89708	- 78892
41-17	795.98	84° 53'	9.99827	8.95029	2.90090	1.85119	2.89917	2.90714	4.75833	- 57323
17-20	1251.00	85° 58'	9.99892	8.84718	3.09726	1.94444	3.09618	3.26194	5.20638	- 160833
20-21	927.62	82° 59'	9.99674	9.08692	2.96737	2.05429	2.96411	3.46421	5.51850	- 329992
21-23	889.82	2° 37'	8.65947	9.99955	2.94930	2.94885	1.60877	3.52533	6.47418	2979733
23-25	924.72	5° 23'	8.97229	9.99808	2.96601	2.96409	1.93830	3.52830	6.49239	3107357
25-47	1591.66	86° 52'	9.99935	8.73767	3.20185	1.93952	3.20120	3.41896	5.35848	- 228284
47-46	1090.75	82° 26'	9.99620	9.11952	3.03772	2.15724	3.03392	3.11015	5.26739	185092
46-44	1119.70	42° 16'	9.82775	9.86924	3.04910	2.91834	2.87685	2.57582	5.49416	- 312007
44-42	559.74	0° 0'	∞	0	2.74799	2.74799	0	0	0	0

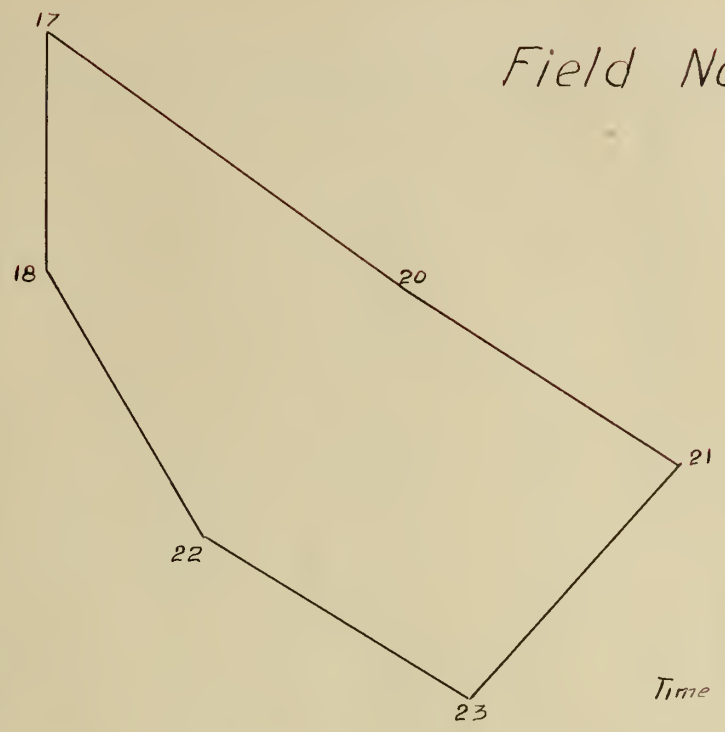
Stadia Area 5104851 sq. ft. = 117.19 acres

Triangulation Area = 117.32

- 0.13

Error $-\frac{1}{902}$

Field No. 3



Oct 3 1911 Time 2:30 – 5:00

Inst. Nau Cloudy Temp 65°

Rod. Erskine Brisk Wind No Vib.

Sta	Obj	Angle	Rod Intercept	Stadia Distance	Triangulation Distance	Difference
17	18					
	20	54° 27'	6.283 *	1256.00	1255.00	+ 1.00
20	17					
	21	182° 59	9.230	925.18	925.96	− 0.78
21	20					
	23	80° 23'	8.886	890.76	890.42	+ 0.34
23	21					
	22	100° 18'	8.940	896.16	894.91	+ 1.25
22	23					
	18	152° 42'	4.303 *	864.66	865.89	− 1.23
18	22					
	17	149° 11'	6.706	672.46	671.68	+ 0.78

Stadia Factor

	Whole Intercept	Half Intercept
20 - 19	8.609	4.295

* Half Intercept

Field No. 3

Line	length	Angle	Log Sin	Log Cos	log length	Log Lat	Log Dept	Log ½ Mean	Log Product	Product
17-20	1256.00	54°21'	9.91042	9.76448	3.09899	2 86347	3.00941	2.70838	5.57185	373120
20-21	925.18	51°21'	9.92579	9.73081	2.96623	2.69704	2.89202	3 14979	5.84783	704400
21-23	890.76	42° 10'	9.82691	9.86993	2.94976	2.81969	2 77667	3.17692	5.99661	992200
23-22	896.16	58° 8'	9.92905	9.72259	2.95238	2 67497	2.88143	2.91555	5.59052	- 389500
22-18	864.66	30° 50'	9.70973	9.93382	2.93685	2 87067	2.64658	2.34556	5.21623	- 164500
18-17	672.46	0° 0'	∞	0	2 82767	2.82767	0	0	0	0

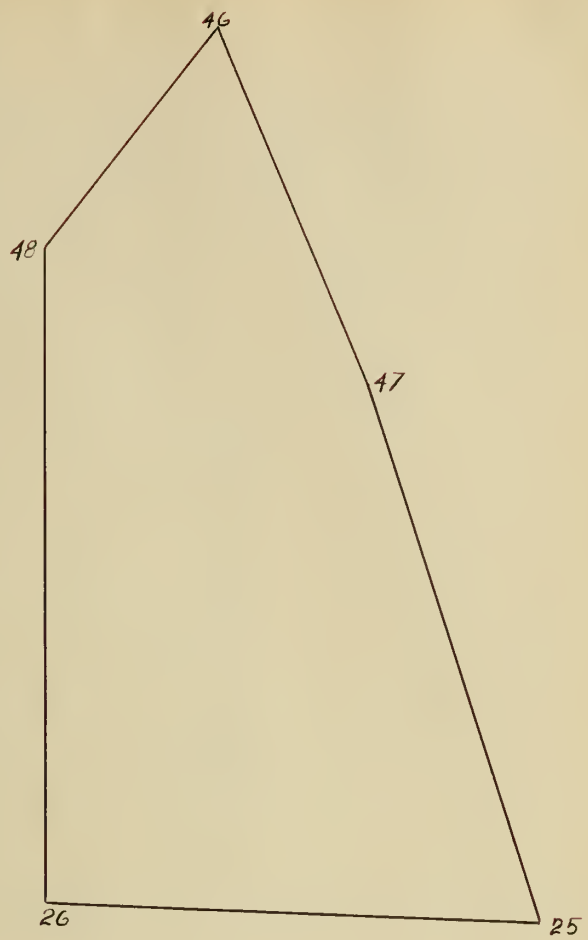
Stadia Area = 1515720 sq.ft. = 34.79 Acres

Triangulation Area = 34.74 "

+0.05 "

Error $+\frac{1}{695}$

Field No. 4



Inst. Erskine

Rod. Nau

Oct 13 1911 Time 1:30 - 4:30

Cloudy Temp 65°

Light Breeze No Vib.

Sta.	Obj.	Angle	Rod Intercept	Stadia Distance	Triangulation Distance	Difference
48	26					
	46	140° 46'	8.055	804.90	804.58	+ 0.32
46	48					
	47	61° 27'	5.471 *	1087.32	1092.88	− 5.56
47	46					
	25	175° 33'	7.930 *	1587.46	1585.70	+ 1.76
25	47					
	26	70° 00'	7.010 *	1403.43	1407.02	− 3.59
26	25					
	48	92° 15'	9.200 *	1441.58	1443.44	− 1.86

Stadia Factor

		Whole Intercept	Half Intercept
19	17	5.500	2.741
	11	5.905	2.948

* Half Intercept

Field No. 4.

Line	Length	Angle	Log. Sin.	Log. Cos.	Log. Length	Log. Lat.	Log. Dept.	Log ½ Mean	Log. Product	Product.
48-46	804.90	39°14'	9.80105	9.88906	2.90574	2.79480	2.70679	2.40575	5.20055	158,690
46-47	1087.32	22°13'	9.57762	9.96650	3.03636	3.00386	2.61398	2.85409	5.85795	721,020
47-25	1587.46	17°46'	9.48450	9.97878	3.20070	317948	2.68520	3.06536	6.24484	1,757,300
25-26	1403.43	87°45'	9.99967	9.59395	3.14719	2.74114	3.14686	2.84721	5.58835	387570
26-48	1441.58	0° 0'	∞	0.00000	3.15884	3.15884	0.00000	0.00000	0.00000	000000

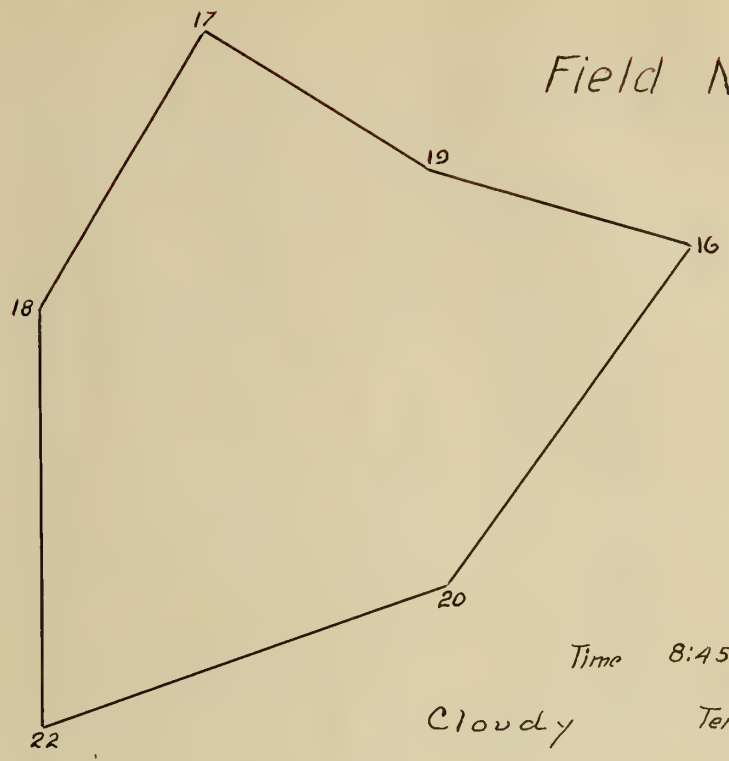
Stadia Area = 1932060 Sq. ft. = 44.35 Acres

Triangulation Area = 44.42 "

-0.07 "

Error - $\frac{1}{635}$

Field No. 5



Inst. Nau

Rod Erskine

Oct. 14, 1911

Time 8:45 - 12:00

Cloudy Temp. 60°

Light Wind No Vib.

Sta.	Obj.	Angle	Rod Intercept	Stadia Distance	Triangulation Distance	Difference
18	22					
	17	149° 11'	6.700	671.46	671.67	− 0.21
17	18					
	19	89° 10'	5.467	548.08	549.73	− 1.65
19	17					
	16	195° 11'	5.670	568.39	569.20	− 0.81
16	19					
	20	70° 16'	8.669	868.50	868.92	− 0.42
20	16					
	22	145° 10'	4.480 *	896.96	896.39	+ 0.57
22	20					
	18	70° 54	4.318 *	864.56	865.89	− 1.33

		Stadia Whole Intercept	Factor Halt Intercept
19	12	4.102	2.051
	11	5.881	2.945

* Halt Intercept

Field No. 5.

Line	Length	Angle	Log. Sin.	Log. Cos	Log Length	Log Lat	Log Dept.	Log ½ Mean	Log Product	Product
18-17	671.46	30°49'	9.70952	9.93390	2.82702	2.76092	2.53654	2.23550	4.99642	- 99,180
17-19	548.08	58°29'	9.93069	9.71829	2.73884	2.45713	2.66953	2.76162	5.21875	165,480
19-16	568.39	73°40'	9.98211	9.44905	2.75464	2.20369	2.73675	3.03500	5.23869	173,810
16-20	868.50	36°04'	9.76991	9.90759	2.93877	2.84636	2.70868	3.04258	5.88894	774,350
20-22	896.96	70°54'	9.97541	9.51484	2.95277	2.46761	2.92818	2.62715	5.09476	124,390
22-18	864.56	0° 0'	∞	0.	2.93680	2.93680	0	0	0	0.

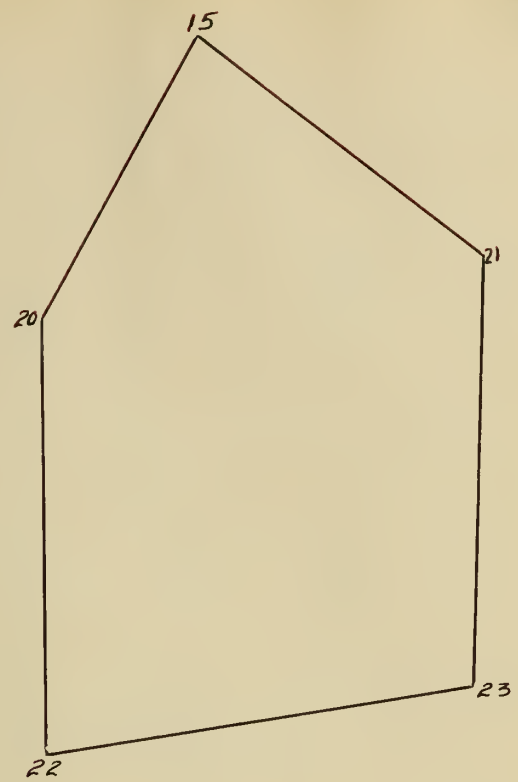
Stadia Area = 1138290 Sq.ft = 26.13 Acre

Triangulation Area = 26.16 "

-0.03 "

Error - 1/872

Field No. 6



Inst. Nav

Rod. Erskine

Oct. 14, 1911 Time 2:00 – 3:15

Cloudy Temp. 55°

Windy No Vib

Sta.	Obj.	Angle	Rod Intercept	Stadia Distance	Triangulation Distance	Difference
20	22					
	15	150° 49′	6.731	674.61	673.30	+ 1.31
15	20					
	21	80° 45′	7.511	751.90	751.20	+ 0.70
21	15					
	23	126° 21′	8.900	890.22	889.95	+ 0.27
23	21					
	22	100° 18′	8.970	894.91	896.92	– 2.01
22	23					
	20	81° 47′	4.488 *	896.39	899.80	– 3.41

Stadia Factor

		Whole Intercept	Half Intercept
19	11	5.897	2.940
	16	5.693	2.840

* Half Intercept

Field No. 6

Line	Length	Angle	Log Sin	Log Cos	Log Length	Log Lat	Log Dept	Log ½ Mean	Log Product	Product
20-15	674.61	29° 11'	9.68807	9.94105	2.82906	2.77011	2.51713	2.21612	4.98623	-96880
15-21	751.90	51° 34'	9.89395	9.79351	2.87616	2.66967	2.77011	2.79480	5.46447	291387
21-23	890.22	2° 5'	8.56054	9.99971	2.94950	2.94921	1.51004	2.95509	5.90430	802233
23-22	894.91	81° 47'	9.99552	9.15508	2.95177	2.10685	2.94729	2.64626	4.75311	56637
22-20	896.39	0° 0'	∞	0	2.95250	2.95250	0	0	0	0

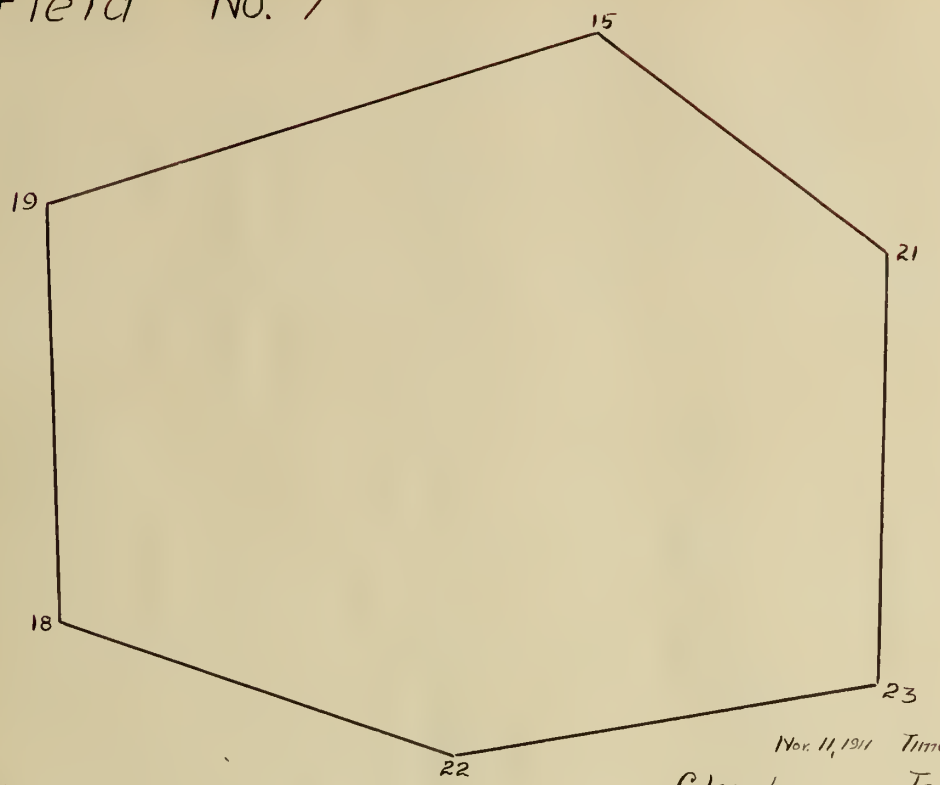
Stadia Area 1053377 sq.ft. = 24.15 Acres

Triangulation Area = 24.18 "

- 0.03 "

Error $-\frac{1}{806}$

Field No. 7



Nov. 11, 1911 Time 3:15–4:30

Inst. Nav Cloudy Temp. 55°

Rod Erskine Hard Wind No Vib.

Sta.	Obj.	Angle	Rod Intercept	Stadia Distance	Triangulation Distance	Difference
19	18					
	15	105° 52'	6.000 *	1201.35	1204.20	− 2.85
15	19					
	21	125° 11'	7.500	749.78	751.90	− 2.12
21	15					
	23	126° 21'	8.928	892.36	890.42	+ 1.94
23	21					
	22	100° 18'	8.950	894.56	894.91	− 0.35
22	23					
	18	152° 42'	4.326 *	866.46	865.89	+ 0.57
18	22					
	19	109° 36'	8.620	861.62	862.73	− 1.11

Stadia Factor

		Whole Intercept	Half Intercept
19	11	5920	2940
	16	5676	2846

* Half Intercept

Field No. 7

Line	Length	Angle	Log. Sin	Log. Cos.	Log. Length	Log. Lat.	Log Dept.	Log ½ Mean	Log. Product	Product
19-15	1201.35	74° 8'	9.98313	9.43680	3.07967	2.51647	3.06280	2.76178	5.27825	- 189780
15-21	749.78	51° 3'	9.89081	9.79840	2.87494	2.67334	2.76575	3.16052	5.83386	682117
21-23	892.36	2° 36'	8.65670	9.99955	2.95054	2.95009	1.60724	3.23514	6.18523	1531930
23-22	894.56	82° 18'	9.99607	9.12706	2.95161	2.07867	2.94768	3.09864	5.17731	150425
22-18	866.46	70° 24'	9.97408	9.52563	2.93775	2.46338	2.91183	2.60595	5.06933	- 117310
18-19	861.62	0° 0'	∞	0	2.93533	2.93533	0	0	0	0

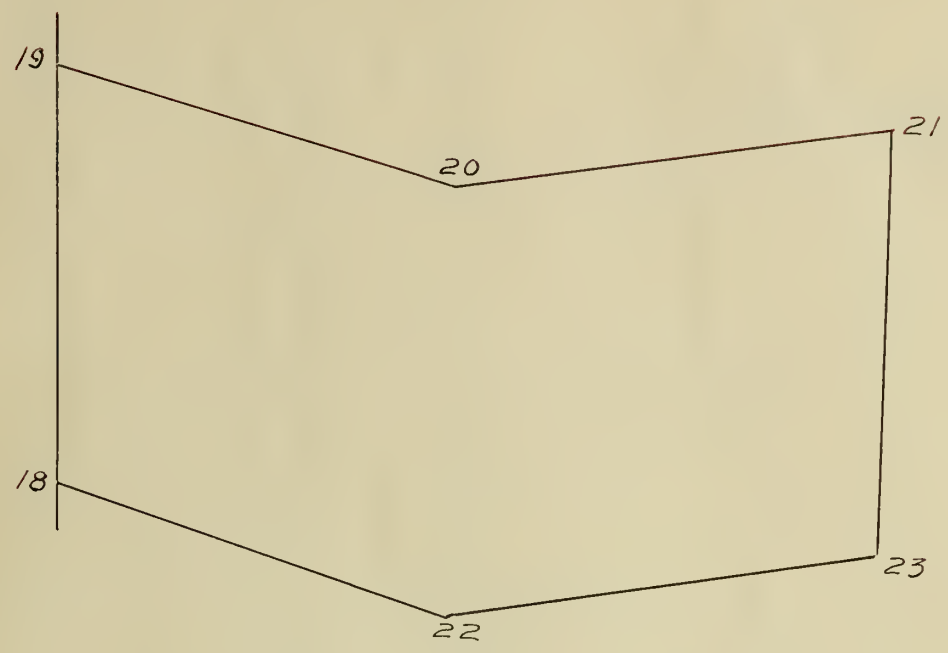
Stadia Area 2057382 sq. ft. = 47.231 Acres

Triangulation Area 47.292 "

−0.061 "

Error $-\frac{1}{775}$

Field No. 8



Inst. Nau — Nov. 11, 1911
Rod. Erskine — Time 2ᵒᵘ-3¼
Cloudy, very windy — Temp. 55°

Sta. Obj.	Angle	Intercept	Stadia Distance	Triangulation Distance	Difference
19 - 20					
18	72° 41′	8.627	862.32	862.73	- 0.39
20 - 21					
19	204° 20′	8.634	863.00	863.05	- 0.05
21 - 23					
20	80° 23′	9.250	924.50	925.96	- 1.46
23 - 22					
21	100° 18′	8.895	889.80	890.42	- 0.62
22 - 18					
23	152° 42′	8.939	893.46	894.91	- 1.45
18 - 19					
22	109° 36′	4.311*	863.46	865.89	- 2.43

Stadia Factor

Intercept	Half.	Full.
19-11	2.940	5.920
16	2.846	5.676

* Half intercept.

Field No. 8.

Line	Length	Angle	Log. Sin.	Log. Cos.	Log. Length	Log. Lat.	Log. Dept.	Log. ½ Mean	Log. Product	Product.
19-20	863.00	72° 41"	9.97986	9.47371	2.93601	2.40972	2.91587	2.61485	5.02457	105,822
20-21	924.50	82° 59"	9.99674	9.08692	2.96591	2.05283	2.96265	3.10813	5.16096	-144,863
21-23	889.80	2° 36"	8.65670	9.99955	2.94929	2.94884	1.60599	3.23586	6.18470	1,530,030
23-22	893.46	82. 18	9.99607	9.12706	2.95107	2.07813	2.94714	3.09983	5.17796	150,648
22-18	863.46	70° 24	9.97408	9.52563	2.93624	2.46187	2.91032	2.61175	5.07362	-118,475
18-19	862.32	0° 0"	∞	0	2.93567	2.93567	0	0	0	0

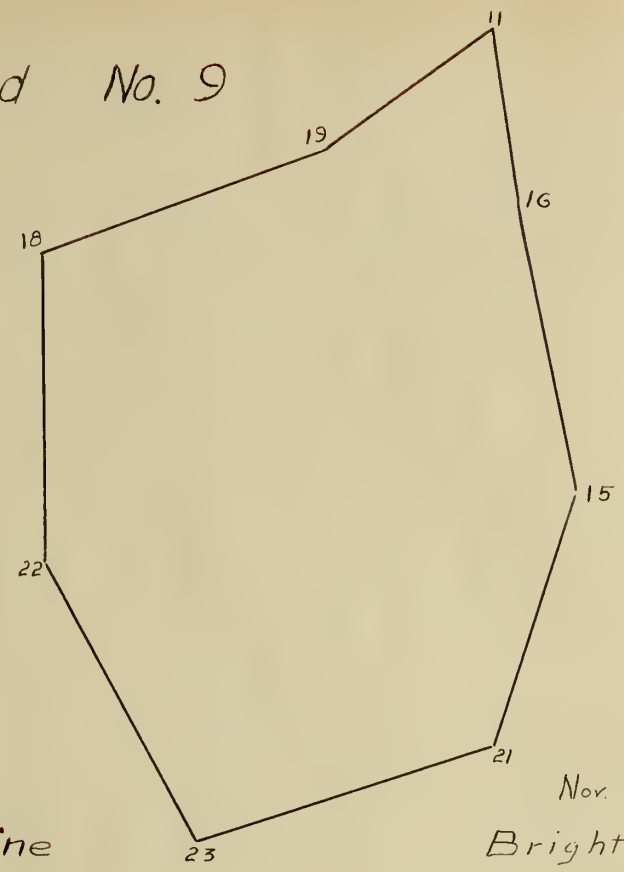
Stadia Area = 1523162 sq. ft = 34.967 Acres

Triangulation Area = 35.022 "

− 0.055 "

Error = $-\frac{1}{650}$

Field No. 9



Nov. 20, '11 Time 1:45 - 3:00

Inst. Erskine Bright, Clear Temp. 50°

Rod. Nau Light Wind No Vib.

Sta.	Obj.	Angle	Rod Intercept	Stadia Distance	Triangulation Distance	Difference
18	22					
	19	109° 36'	8.600	863.40	862.73	+ 0.67
19	18					
	11	196° 00'	5 863	588.94	590.42	- 1.48
11	19					
	16	61° 53'	5.052	507.60	508.11	- 0.51
16	11					
	15	183° 4'	4.169 *	834.08	834 73	- 0.65
15	16					
	21	150° 7'	7.472	750.28	751.90	- 1.62
21	15					
	23	126° 21'	8.878	891.28	890.22	+ 1.06
23	21					
	22	100° 18'	8.950	898.50	894.91	+ 3.59
22	23					
	18	152° 21'	4.309 *	862.08	865.89	- 3.81

Stadia Factor

		Whole Intercept	Half Intercept
19	11	5.863	2.945
	16	5.680	2.848

* Half Intercept

Field No. 9

Line	Length	Angle	Log. Sin.	Log. Cos.	Log Length	Log Lat	Log Dept	Log ½ Mean	Log Product	Product
18-19	863.40	70° 24'	9.97408	9.52563	2.93621	2.46184	2 91029	2.60926	5.07110	-117787
19-11	588.94	54° 24'	9.91014	9.76501	2.77007	2.53508	2.68021	3.02235	5.55743	-360933
11-16	507.60	7° 29'	9.11474	9.99629	2.70552	2.70181	1.82026	3.12232	5.82413	667000
16-15	834.08	10° 36'	9.26470	9.99252	2.92121	2.91373	2.18591	3.15688	6.07061	1176540
15-21	750.28	19° 17'	9.51883	9.97492	2.87522	2.85014	2.39405	3.14236	5.99250	982870
21-23	891.28	72° 56'	9.98044	9.46758	2.95001	2.41759	2.93045	2.92325	5.34084	219200
23-22	898.50	27° 22'	9.66246	9.94845	2.95352	2.90197	2.61598	2.31279	5.21476	-163970
22-18	862.08	0° 0'	∞	0	2.93555	2.93555	0	0	0	

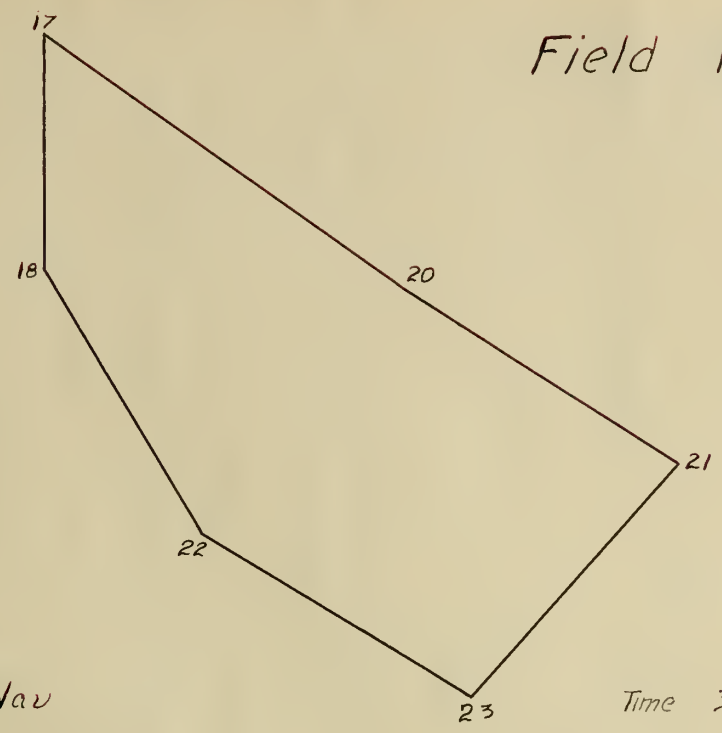
Stadia Area 2402920 sq.ft = 55.17 Acres

Triangulation Area 55.27 "

— 0.10 "

Error $-\frac{1}{553}$

Field No. 10



Inst. Nau Time 3:00 – 4.00

Rod. Erskine Cloudy Temp. 50°

Nov 20 1911 Light Wind No Vis

Sta.	Obj.	Angle	Rod Intercept	Stadia Distance	Trigonometrical Distance	Difference
17	18					
	20	54° 29'	6.256 *	1251.20	1255.00	– 3.80
20	17					
	21	183° 00'	9.230	926.57	925.96	+ 0.61
21	20					
	23	80° 22'	8.890	892.48	890.42	+ 2.06
23	21					
	22	100° 18'	8.939	897.40	894.91	+ 2.49
22	23					
	18	152° 41'	4.309 *	862.08	865.89	– 3.81
18	22					
	17	149° 11'	6.708	673.66	671.68	+ 1.98

Stadia Factor

		Whole Intercept	Half Intercept
19	11	5.863	2.945
	16	5.680	2.848

* Half Intercept

Field No. 10

Line	Length	Angle	Log. Sin.	Log Cos	Log Length	Log Lat	Log Dept	Log ½ Mean	Log Product	Product
17-20	1251.20	54° 27′	9.91042	9.76448	3.09733	2.86181	3.00775	2.70672	5.56853	370200
20-21	926.57	57° 27′	9.92579	9.73081	2.96688	2.69769	2.89267	3.14876	5.84645	702100
21-23	892.48	42° 10′	9.82691	9.86993	2.95059	2.82052	2.77750	3.17595	5.99647	991900
23-22	897.40	58° 08′	9.92905	9.72259	2.95299	2.67558	2.88204	2.91321	5.58879	388000
22-18	862.08	30° 50′	9.70973	9.93382	2.93555	2.86937	2.64528	2.33616	5.20553	160500
18-17	673.66	0° 0′	∞	0	2.82844	2.82844	0	0	0	0

Stadia Area 1515900 sq. ft. = 34.80 Acres

Triangulation Area 34.74 "

+ 0.06 "

Error + 1/580

Table No. 1.

Field No	Date	Weather Conditions	Area in Acres			Error	Instrument-man	Computation in hrs.
			Triangulation	Stadia	Difference			
1	Sept. 26, '11	Temp. 65° Clear Light Breeze No Vib Time 1:30 – 5:00	55.26	55.19	–0.07	1:790	Erskine	2 ½
2	May 27, '11	Temp. 80° Clear & Bright 9:30-12:00 Medium Wind. Vib. Time 3:30- 5:00	117.32	117.19	–0.13	1:902	"	4.0
3	Oct. 3, '11	Temp 65° Cloudy, Light Breeze Slight Vib. Time 2:30 – 5:00	34.74	34.79	+0.05	1:695	Nau	2.0
4	Oct 13. '11	Temp 65° Cloudy, Light Breeze No Vib. Time 1:30 – 4:30	44.42	44.35	–0.07	1:635	Erskine	1 ½
5	Oct 14, '11	Temp 60° Cloudy, Windy. No Vib. Time 8:45 – 12:00	26.16	26.13	–0.03	1:872	Nau	2.0
6	Nov 10, '11	Temp 55° Light Clouds Wind. No Vib. Time 2:00 – 3:15	24.18	24.15	–0.03	1:806	Erskine	1 ½
7	Nov 11, '11	Temp. 55° Light Clouds, very high Wind No Vib. Time 3:15 – 4:30	47.29	47.23	–0.06	1:775	Nau	2
8	Nov 11, '11	Same as No. 7. Time 2:00 : 3:15	35.02	34.97	–0.05	1:650	"	2
9	Nov 20 '11	Temp. 50° Air Hazy Light Wind No Vib Time 1:45 – 3:00	55.27	55.17	–0.10	1:553	Erskine	2 ½
10	Nov 20 '11	Same as No. 9. Time 3:00 – 5:00	34.74	34.80	+0.06	1:580	Nau	2.

Table No. 2.

Field No	Linear Measurement		Error in	
	Triangulation	Stadia	Perimeter	Area.
1	6198.91	6195.97	- 1:2026	-1:790
2	9706.24	9713.37	+.1:1390	-1:902
3	5503.86	5505.23	+1:4020	+1:695
4	6333.62	6324.69	-1:710	-1:635
5	3521.80	3517.95	-1:900	-1:872
6	4111.17	4108.03	-1:1310	-1:806
7	5370.05	5366.13	-1:1370	-1:775
8	5302.96	5306.54	+1:1480	-1:650
9	6198.91	6196.16	-1:2140	-1:553
10	5503.86	5503.37	-1:11700	+1:580.

CONCLUSIONS.

The errors in eight of the fields were negative and in two they were positive, as is shown in Table 1. The smallest error was in field No. 2 and was - 1:902, and the largest error was in field No. 9 and was - 1:553. The average accuracy for the ten fields was 1: 726.

Each of the observers was transitman for the survey of five fields. All of Mr. Erkine's errors were negative and had an average value of 1:737. On the other hand, two of Mr. Nau's errors were positive and three were negative, and had an average value of 1:715. This shows the difference in the personal equation of the two observers. Since all of Mr. Erskine's readings were low, in practice he should add a certain proportion to his readings; while Mr. Nau, whose readings were both positive and negative, should depend upon the errors compensating.

Table 2 contains the triangulation and the stadia perimeters of each of the fields, and also the fractional error in both the linear measurements and the area. An average accuracy in linear measurement of 1:2719 was obtained in a total length of 57751 feet. The smallest error was in field No. 10 and was - 1:11700, and the largest was in field No. 4 and was - 1:710. Three of the errors in linear measurement were positive but in only one case did a positive error in the area result. This occurred in field No. 3.

The total time required to survey the ten fields was 23 hours, and 22 hours were necessary for the computations of the areas. The average size of the fields was 46 acres, and the

average number of sides to a field was six+ . Ordinarily fields of this size have only four sides, and only four set-ups of the transit are necessary in their survey. Hence it is safe to say that of the 23 hours required for the field work, 8 or 10 hours could have been saved if the surveys had been confined to a smaller number of fields having the same total perimeter.

In some recent surveys made by Mr. Paul Kircher, a senior civil engineering student of the University of Illinois, in connection with thesis work, four farms having a total perimeter of 40,685 feet were surveyed in 24.7 hours by the transit and tape method, which is at the rate of 1645 feet of traverse per hour. Assume that the surveys of the fields in this investigation could have been made in 15 hours instead of 23, if the number of sides to each field had been normal. This would give a rate of 3850 feet of traverse per hour, which is more than twice the rate attained in the transit and tape survey.

With the above data in mind, assume a field of 640 acres and compare the two methods of surveying. The perimeter would be 21, 120 feet which would require 13.5 hours by the transit and tape method, and 5.5 hours by the transit and stadia method. If the work is done by the surveyor at $1.00 per hour and an assistant at $0.25 per hour, the total cost per hour is $1.25. In the above survey the saving of eight hours by the transit and stadia method reduces the cost of the survey by $10.00. While these assumptions are probably in error, it is easily seen that the stadia method is much the quicker and hence less expensive; but since it is less accurate, its use is limited by the value of the land.

In the transit and tape surveying an accuracy in the area of 1:3000 is ordinarily considered acceptable work. This value is based on an accuracy in the linear measurement or 1:5000, which is rarely exceeded in ordinary work. The change in the length of the tape due to changes in temperature is never taken into consideration by surveyors. Steel tapes are standard length at about 65° F, and a change of 15° in temperature causes a change in the length of the tape of 0.01 ft. So if surveying work is done say 35° or 95°F an accumulative error of 1:5000 results. An error of 1:3000 in the area can probably be obtained on cleared land and where conditions are favorable, but such conditions are only to be had on the higher-priced lands, which are cleared of all weed, underbrush, etc. On the other hand cheap land is generally covered with weed, etc., which would reduce the accuracy of the chaining, but would not effect the accuracy or speed of the stadia method. A fair value of the accuracy of a chain survey under such conditions would be 1:1500 or about twice the accuracy of the stadia method. Besides reducing the accuracy of the survey, the underbrush and weeds would retard the progress of the work to such an extent that 1000 ft. of traverse per hour by the transit and tape method would be the limit of speed. At this rate the saving in the cost of the survey of 640 acres by the stadia would be $19.50. In order for the saving in the cost of the survey to be offset by the difference in the accuracy, the cost of the land must be $47.00 an acre.

The surveying work in each of the methods in the above discussions were performed by inexperienced men, so that the time required by both of them is more then would be required by experienced surveyors, so that the saving given above is too large ; but the accuracy of the two methods would be more nearly the same, because experienced men in the use of the stadia could increase the accuracy of the stadia method, while the accuracy of the transit and tape method would not necessarily be effected.

Frequently the owner of medium -priced land would prefer a saving on the cost of survey at the expense of accuracy, in which case the stadia method is desirable. After considering the fact that under the conditions ordinarily prevailing on cheap land, the time for a transit and tape survey is two or three times that required for a stadia survey while the relative accuracy of the latter is better than one-half - providing the surveyor allows for personal equation and errors due to climatic conditions - then the conclusion is obvious that for land valued at over $50.00 an acre the usual way of surveying is the better because the increased cost of surveying is offset by the increased accuracy. Therefore the stadia method is applicable to the survey of land worth less than $50.00 an acre.